# Large Quark Rotations Neutrino Oscillations and Proton Decay

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July 2001

**Abstract**

The large freedom in the SM fermionic mass matrices allows for large RH and LH quark rotations. This is a natural possibility in view of the observed large leptonic mixing. Proton decay and especially its gauge mediated decay is sensitive also to those mixing angles which are non-relevant in the SM. A model with realistic mass matrices and large rotations is presented. It is shown that the large leptonic mixing leads to enhancement of the proton decay branching ratios involving muons.

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Many *different* sets of fermionic mass matrices are consistent with the phenomenology of the SM. This is due to the huge freedom in the fermionic rotations in the SM:
$V_{CKM}$—gives only the *difference* between the LH up and down quark mixing angles.
RH ROTATIONS—are unobservable in the SM (are equal to the LH rotations only if the mass matrices are hermitian).
All quark mixing angles can be large, and in fact we know that large RH quark rotations go naturally with the observed large LH leptonic mixing[1] in some GUT's.
In the SM the mass matrices are arbitrary hence the model must be extended to predict them (if not for many other reasons). To find out what the "fundamental" mass matrices in the extended theory are, one needs to know also the mixing angles which are "non relevant" in the SM.
RH mixing can be observed via RH currents directly, or indirectly (if $W_R$ is very heavy) in: Baryon-asymmetry induced via Leptogenesis[2] (the relevant rotations are here RH !), Leptoquark interactions, Radiative corrections e.t.c.
In particular, the proton decay branching ratios are the best observables to look for the "non-relevant" rotations. D=6 gauge mediated proton decays involve all RH and LH mixing angles. They are also interesting for the following reasons:
D=5 sparticle induced proton decays depend on yet unobserved sparticles and couplings and therefore involve many unknown parameters. This freedom however does not save SUSY SU(5) from being ruled out[3]. Also extensions of SU(5) and SO(10) must be carefully constructed and are yet on the verge of being excluded[1] [4]. A natural alternative would be to suppress not only the D=4 but also the D=5 contributions (e.g. via a symmetry).
Gauge mediated decays involve only known coupling and masses and the predicted branching ratios are therefore much more reliable in this case. They are the real test of GUTs, because D=5 decays are allowed also in non-GUTs as well. Also, there are recently quite a few models with $M_X$ lower than $10^{16}$ GeV [5] where D=6 proton decay can be observable in the near future.

To illustrate our point let me present a renormalizable SUSY SO(10) model with large mixing angles[6]. It is based on mass matrices with a non-hermitian Fritzsch texture induced via a $U(1)_F$ global family group. The free parameters are chosen in such a way that all mixing angles will be calculable in terms of the known fermionic masses and mixing. The best fit for the mixing angles in the case of the favored LMA-MSW solution to the solar neutrino puzzle gives naturally large mixing angles.

1. The Quark LH and RH mixing angles at the GUT scale:
   $\theta^u_{L12} = -0.077, \quad \theta^u_{L23} = -1.48, \quad \theta^u_{L13} = -4 \times 10^{-8}.$
   $\theta^u_{R12} = -0.045, \quad \theta^u_{R23} = -2.2 \times 10^{-4}, \quad \theta^u_{R13} = -1.1 \times 10^{-3}.$
   $\theta^d_{L12} = 0.15, \quad \theta^d_{L23} = -1.44, \quad \theta^d_{L13} = 1 \times 10^{-5}.$
   $\theta^d_{R12} = -0.33, \quad \theta^d_{R23} = -3 \times 10^{-3}, \quad \theta^d_{R13} = 6 \times 10^{-2}.$

2. The mixing angles of the Charged Leptons:

   $\theta^\ell_{L12} = -1.17, \quad \theta^\ell_{L23} = 1.44, \quad \theta^\ell_{L13} = 0.0002.$
   $\theta^\ell_{R12} = 0.002, \quad \theta^\ell_{R23} = -0.003, \quad \theta^\ell_{R13} = 0.002.$

Table 1: Proton and neutron decay branching ratios

| proton decay channel | % no mixing | % LA-MSW | neutron decay channel | % no mixing | % LA-MSW |
|---|---|---|---|---|---|
| $p \rightarrow e^+\pi^0$ | 33.6 | 17.5 | $n \rightarrow e^+\pi^-$ | 62.86 | 32.5 |
| $p \rightarrow \mu^+\pi^0$ | – | 16.1 | $n \rightarrow \mu^+\pi^-$ | – | 30.0 |
| $p \rightarrow e^+K^0$ | – | 4.6 | $n \rightarrow e^+\rho^-$ | 9.7 | 5.0 |
| $p \rightarrow \mu^+K^0$ | 5.8 | 2.7 | $n \rightarrow \mu^+\rho^-$ | – | 4.6 |
| $p \rightarrow e^+\eta$ | 1.2 | 0.6 | $n \rightarrow \nu_e^C\pi^0$ | 15.1 | 9.2 |
| $p \rightarrow \mu^+\eta$ | – | 0.6 | $n \rightarrow \nu_e^C K^0$ | – | 2.6 |
| $p \rightarrow e^+\rho^0$ | 5.1 | 2.7 | $n \rightarrow \nu_e^C\eta$ | 0.6 | 0.3 |
| $p \rightarrow \mu^+\rho^0$ | – | 2.5 | $n \rightarrow \nu_\mu^C\pi^0$ | – | 5.1 |
| $p \rightarrow e^+\omega$ | 16.9 | 8.8 | $n \rightarrow \nu_\mu^C K^0$ | 1.7 | 0.0 |
| $p \rightarrow \mu^+\omega$ | – | 8.1 | $n \rightarrow \nu_\mu^C\eta$ | – | 0.2 |
| $p \rightarrow \nu_e^C\pi^+$ | 32.3 | 19.7 | $n \rightarrow \nu_e^C\rho^0$ | 2.3 | 1.4 |
| $p \rightarrow \nu_\mu^C\pi^+$ | – | 10.9 | $n \rightarrow \nu_e^C\omega$ | 7.7 | 4.7 |
| $p \rightarrow \nu_\mu^C K^+$ | 0.1 | 0.2 | $n \rightarrow \nu_\mu^C\rho^0$ | – | 0.8 |
| $p \rightarrow \nu_e^C\rho^+$ | 4.9 | 3.0 | $n \rightarrow \nu_\mu^C\omega$ | – | 2.6 |

These were used in the calculation of the branching ratios for the proton and neutron decays. The following branching ratios result and are presented together with the case where the mixing is neglected in Table 1.

The branching ratios of the nucleon decay into muons are strongly enhanced and are as large as the decay into $e^+\pi^0$ .
The enhancement of the muon branching ratios is a unique feature of our model because the decay mode $p \rightarrow e^+\pi^o$ is not negligible also in the $d = 5$ induced decays[7]. In view of the fact that this enhancement is the effect of the large observed leptonic mixing on the $d = 6$ nucleon decay, we suggest that *the observation of a considerable rate for the decay* $p \rightarrow \mu^+\pi^o$ *will be a clear indication for a gauge mediated proton decay.*

One can say in general, that the branching ratios of the nucleon decay can teach us about the "fundamental" mass matrices as they depend on all mixing angles. The present huge freedom in the mass matrices would then be strongly restricted and one could better understand the origin of the fermionic masses.

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